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Original Research

Test-retest reliability of ınspiratory muscle endurance testing in healthy adults

Inspiratory muscle endurance testing in healthy adults

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Abstract

Aim: The optimal test for inspiratory muscle endurance has not been determined. The aim of this study was to investigate the repeatability of the incremental load test, which is frequently used in the clinic.

Materials and Methods: Thirty healthy adults aged 18-35 years were included in the study. The anthropometric characteristics of the subjects were recorded. Physical activity levels were evaluated with the International Physical Activity Questionnaire. They performed spirometry testing, maximal inspiratory pressure assessment and incremental load test. The incremental load test was started with 30% of the maximal inspiratory pressure and the pressure was increased at one-minute intervals. The test was repeated after two weeks.

Results: Test retest reliability of the incremental load test was found excellent (ICC: 0.979; p< 0.001). There was no significant difference between the breathing parameters, rate of perceived exertion and duty cycle of the test and retest (p> 0.05).

Discussion: The incremental load test is repeatable to evaluate inspiratory muscle endurance in healthy adults. Studies investigating repeatability in the clinical setting and considering multiple repeat tests are required.

Keywords

Respiratory Muscles, Respiratory Muscle Endurance, Test-–Retest Reliability, Work Of Breathing, Maximal Inspiratory Pressure, Maximal Respiratory Pressures

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Introduction

Inspiratory muscle function is characterized by strength and endurance. Inspiratory muscle strength is defined as the capacity to generate maximum force, while inspiratory muscle endurance is described as the ability to carry out a task for a specified period of time. Maximal inspiratory pressure (MIP), which is an inspiratory muscle strength measurement method frequently used in the clinic, is accepted as an indicator of respiratory muscle function. However, since inspiratory muscles are used at a submaximal level in daily life, the evaluation of their endurance is more functional than strength measurement. Unlike the measurement of inspiratory muscle strength, there is not yet a generally accepted measurement method for the evaluation of inspiratory muscle endurance [1]. External loading, ventilatory endurance and time trials are methods that are generally used to evaluate inspiratory muscle endurance. Maximal voluntary ventilation (MVV) and maximal sustainable ventilation (MSV) are time trials that aim to provide maximum ventilation within a certain period of time. The 10-15 second MVV test is too short and insufficient to assess respiratory muscle endurance. It is no longer recommended for respiratory muscle endurance testing in patients with respiratory muscle weakness. The MSV test, which measures ventilation that can be sustained over a long period of time (e.g. 12-15 minutes), is a more significant measure of respiratory muscle endurance than MVV. The MSV test, which measures ventilation that can be sustained over a long period of time (e.g. 12-15 minutes), is a more significant measure of respiratory muscle endurance than MVV. However, there is no consensus on which MSV protocol to use [2, 3]. Isocapnic hyperpnea is an endurance test that includes both inspiratory and expiratory muscle loading. Loads are determined as a percentage of MVV. The need for costly special equipment limits the use of the test in the clinic [2, 4]. External load tests, which consist of constant load test and incremental load test, have been used more frequently in recent years because they allow the use of portable and low-cost devices. A constant load test is an external load test in which threshold load (a percentage of the MIP) is maintained until task failure (Tlim) [5, 6]. In an incremental load test, the inspiratory load is increased as a percentage of the MIP at a specified time or breath intervals. Peak pressure is the maximum inspiratory mouth pressure maintained in the last step [7, 8]. Many authors recommend the use of incremental load test instead of constant load test, as they are less affected by participant motivation, tolerated more easily, reflect the response to treatment more accurately, and have higher reproducibility in the pediatric group and patient population [1, 3, 4, 9]. Since external load tests are affected by breathing patterns, it is recommended to control respiratory characteristics such as mouth pressure, flow and inspiratory volume during testing. However, the control of these parameters causes the test procedure to be complicated. For this reason, some authors state that it is necessary to measure with devices that can record respiratory characteristics in order to overcome this problem [3]. The aim of this study was to evaluate the repeatability of the incremental load test in a healthy adult population with a portable device (PowerBreathe KH2) that measures mouth pressure, flow and inspiratory volume during testing. Our hypothesis was that the incremental load test would be repeatable in healthy adult subjects who did not have factors affecting the respiratory muscle.

Material and Methods

Subjects were recruited from an ongoing observational study investigating respiratory muscle endurance in healthy adults (clinicaltrials.gov identifier: NCT05237427). The study was approved by the Non-Interventional Clinical Research Ethics Committee of Kutahya Health Sciences University (2020/04-11). We included at least 20 % of the total number of participants planned to be included in the ongoing study (120 subjects) in the test-retest analysis [10]. Thirty (11 males, 19 females) healthy non-smoker adult subjects aged 18-35 years were included in the study. Adults with respiratory tract disease, heart disease, neuromuscular disease, scoliosis, previous thoracic surgery, and previously experienced respiratory muscle endurance protocol were not included in the study [9, 11].

Anthropometric Assesment

Body weight was assessed with a digital scale in the orthostatic position, without shoes, with minimal clothing (Tanita BC 730, Tokyo, Japan) [12]. Height was measured with the feet parallel and adjacent to each other, the arms extended by the body, and the head in a neutral position (Seca 213, Hamburg, Germany) [13]. Body mass index (BMI) was calculated by dividing body weight by the square of height (kg/m^2).

Pulmonary Function Test (PFT)

Pulmonary function test measurements were made to confirm that the respiratory function parameters of the subjects were within the normal range. Forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) were measured with a portable spirometer (Cosmed Pony FX, Inc, Italy). The test was carried out in a sitting position. The highest of the three maneuvers with 95% agreement with each other was selected for analysis. PFT parameters were expressed as a percentage of expected values for age, height, body weight, and gender [14].

Maximal Voluntary Ventilation (MVV)

MVV measurements were made with a portable spirometer (Cosmed Pony Fx, Inc, Italy). The participant was asked to breathe as deeply and rapidly as possible (90-110 breaths/min) for 12 seconds. The highest value of the three measurements was used for value analysis [15].

Respiratory Muscle Strength

An electronic mouth pressure measuring device (POWERbreathe KH2, POWERbreathe International Ltd, UK) was used for respiratory muscle strength. The participant was asked to do the maximum expiration up to the residual volume, and to make a maximum inspiration for 1-3 seconds after the nose was closed with the help of a clip. The maximum inspiratory pressure (MIP) formed at the mouth was measured. The measurements were repeated nine times, one minute apart, with no difference of 10 cmH_2O or 10% between results. Equations of Black and Hyatt were taken as references in the interpretation of the measurements [3, 16].

Respiratory Muscle Endurance

Respiratory muscle endurance test was evaluated with an incremental load test. After the device (POWERbreathe KH_2, POWERbreathe International Ltd, UK) was placed in the mouth, the nose was closed with a clamp, and the participant was asked to breathe through the mouth. The test started with 30% of the maximal inspiratory pressure, and the pressure was increased by 10% at one-minute intervals. Breathing frequency was fixed at 15 breaths/minute by a metronome. In the last 10 seconds of each load level, subjects were requested to rate of perceived exertion (RPE) through the Modified Borg Scale. The test was terminated when the participant was too tired to continue or was unable to open the valve three consecutive times. The outcome measure, called sustained maximal inspiratory pressure (SMIP), was defined as the highest load, in percentage of MIP sustained for full one minute. The measurement was repeated at least two weeks later to evaluate the reproducibility reproducibility [3, 6, 17].

Physical Activity

Physical activity level was assessed with International Physical Activity Questionnaire-Short Form (IPAQ-SF). It is used to determine the physical activity level and sedentary life styles of individuals between the ages of 15 and 69. The physical activity score is calculated by converting the questionnaire score to Metabolic Equivalent of Task (MET- min/week, 1 MET=3.5 ml/kg/min). Moderate and intense physical activity and durations of walking and sitting in the previous seven days were evaluated with the IPAQ-SF. Physical activity level was classified as 'inactive' for values lower than 600 MET-min/week, 'minimally active' for values of 600–3000 MET-min/week, and 'active' for values over 3000 MET-min/week [18].

Statistical analyzes

Statistical analyzes were performed using the statistical package program SPSS 15.0. The conformity of the variables to the normal distribution was evaluated with the Shapiro-Wilk test. The repeatability of the test was determined by the intraclass correlation coefficient (ICC). The difference in respiratory parameters was evaluated with the Wilcoxon Test. Statistical significance level was accepted as 0.05.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

Thirty subjects were evaluated. Physical and demographic characteristics of the subjects are given in Table 1. According to the pulmonary function testing, the subjects' FEV1 and FVC values are in the normal range. There was no respiratory muscle weakness based on MIP results. The subjects had a moderate level of physical activity.

Test-–retest reliability of the incremental load test was found excellent (ICC: 0.979; p< 0.001) (Figure 1).

Reliability parameters obtained for SMIP are summarized in Table 2. There was no significant difference between the breathing parameters, RPE and the duty cycle of the test and retest (Table 3).

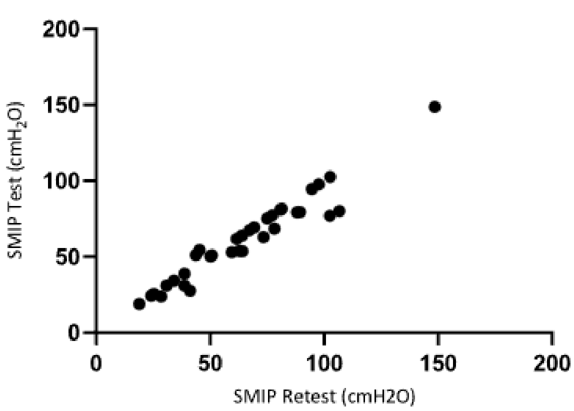

Figure 1. Correlation between test and retest.

Table 1. Characteristics of the subjects.

n=30	Mean±SD
Age (y)	24.37±5.6
Gender n (M/F)	11/19
Body mass index (kg/m²)	24.96±5.05
Pulmonary function testing (% predicted)	
FVC	99.23±9,68
FEV1	95,23±6,94
MVV	88.42±17.42
Inspiratory muscle strength	
MIP (cmH_2O)	96.58±23.43
Physical activity level	
IPAQ (MET-min/week)	1167.11±937.88

Abbreviations: MVV, maximal voluntary ventilation; MIP, maximal inspiratory pressure; IPAQ, international physical activity questionnaire.

Table 2. Test-retest reliability of the incremental load test.

	Mean ± SD Test	Mean ± SD Retest	p-value	ICC (95 % CI)	95 % Confidence Interval	
					Lower Bound	Upper Bound
SMIP (cmH_2O)	65.77±26.33	69.4±28.13	< 0.001	0.979	0.955	0.990

Abbreviations: ICC, Intraclass Correlation Coefficient; CI, confidence interval; SMIP, sustained maximal inspiratory pressure.

Discussion

Table 3. Variables of inspiratory muscle endurance test.

Variables	Test Mean ± SD	Retest Mean ± SD	z	p
Duty cycle (i/tot)	0.48±0.06	0.47±0.06	-0.355	0.72
RPE (Modified Borg Scale)	6.73±2.10	6.63±2.47	-0.388	0.70
Mean Pi (cmH_2O)	29.94±8.84	29.34±9.73	-0.936	0.35
Mean insp. Flow (L/s)	0.79±0.37	0.90±0.56	-1.384	0.17
Mean insp. volume (L)	1.30±0.41	1.44±0.60	-1.008	0.31
Mean power (Watts)	2.30±1.68	2.80±2.86	-1.373	0.17
WOB/breath (Joules)	59.13±31.57	67.47±49.47	-0.751	0.45

Abbreviations: Pi: inspiratory pressure, Insp.: inspiratory, WOB: Work of Breathing, z: Wilcoxon T test value

To the best of our knowledge, this is the first study to examine the repeatability of incremental load test by recording continuously flow, volume, pressure and WOB responses during the test. The incremental load test was repeatable with excellent test retest reliability in healthy non-smoker adults with moderate levels of physical activity. The pressure reached (SMIP) was on average 7% higher in the second test. This value is considered acceptable as the learning factor may have an effect on the result. In the literature, different opinions on this subject have been reported. Sturdy et al. who performed an incremental endurance test in 10 COPD patients with moderate severe obstruction, stated that not accounting the learning effect would result in underestimating test [19]. Conversely, Martyn and colleagues reported in their study with healthy subjects that the subjects were able to tolerate gradually increasing load in the incremental test, and therefore the test result would not be influenced by the learning effect [6]. Subjects' age, health status, and motivation may lead to divergence of findings. In this study we standardized respiratory frequency to 1:2 with a metronome, establishing a frequency of 15 breaths per minute, according to the resting respiratory rate. Subjects had no difficulty in complying with this respiratory rate. Some researchers stated that IME was not affected by respiratory frequency and subjects did not need to be restricted about respiratory rate [20]. In some studies, the respiratory rate was not predetermined, but only recorded during the test [1, 4, 19]. But small changes in the duty cycle may affect the endurance measurement results such as pressure reached and time [17, 21]. Eastwood et al. emphasized that respiratory parameters and RPE were affected by the change of respiratory frequency in repeated tests, in their studies in which they did not control the respiratory frequency. They also stated that differences in breathing pattern in consecutive tests may affect the maximal threshold pressure reached in the test [22]. Moreover, to accurately interpret the change in test results as a change in respiratory muscle endurance, measurements in which the breathing pattern is controlled should be preferred [1]. For this reason, many authors state that respiratory frequency should be fixed during inspiratory muscle endurance testing [1, 3]. Monitoring more specific measures of the respiratory cycle may better characterize the test [4]. Since breathing pattern affects muscle performance, respiratory characteristics should be checked during the test. However, since the control of these parameters leads to the complexity of the method, it is recommended to at least record them to ensure standardization. The device we used for testing stored the data of breathing caharacteristics like mouth pressure, inspiratory volume, flow, power and WOB continuously. Recording these parameters may be important for interpreting adaptive changes such as reaching high inspiratory rates in a shorter time, increasing inspiratory volume after educational interventions, or detecting external load, inspiratory flow and volume differences in different patient populations [3]. Maximal voluntary ventilation is a ventilatory endurance test that is highly dependent on the subject's cooperation, motivation and respiratory system mechanics (obstructive or restrictive) [23]. Since the test measurement is simple and short, it is used as a measurement of respiratory muscle endurance in different populations. However, from a physiological point of view, it is no longer recommended to evaluate respiratory muscle endurance, considering that a 12-15 second test would be insufficient to evaluate endurance [3]. It has already been stated that MVV is not sensitive to changes in respiratory endurance that occur with training [24]. Also, not only inspiratory muscles but also expiratory muscles are recruited in MVV measurement [25]. In our study, there was a moderate relationship between MVV and SMIP. The moderate correlation between MVV and IME in our study, confirms this recommendation and comments. The study also presents some limitations. The sample size may constitute a limitation of the study. The present study only incorporated test-retest sessions. Therefore, future studies should consider multiple repeat tests to confirm our findings. Further studies are also required to evaluate reproducibility in clinical settings.

Conclusion

In conclusion, incremental load test using the POWERbreathe KH_2 device is repeatable to evaluate inspiratory muscle endurance in healthy adults. Generation of reference equations can contribute to a better assessment of individuals.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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